

### **Remarks**

Claims 1-14 are pending in this application. Claims 1-14 now stand rejected. Claims 1 and 14 have been amended.

### **Response to Arguments**

In response to paragraph 2 of the outstanding office action, Applicant wishes to clarify his argument. Claim 1 recites that *coarse* straw ash particles do not enter a flow of a combustion gas, not that *no* ash particles enter the flow of gas. The depressions of claim 1 allow for the coarse ash particles to completely combust and prevents them from entering the gas flow. Due to the nature of straw fuel, fine ash particles may enter the flow of gas, but are subsequently combusted in the first and second combustion chamber. As argued in the previous response, charring of the outer layers of the straw bale leads to large amounts of light, un-combusted components that may be whirled up in the combustion chamber. Claim 1 recites that the combustion gas passes through the grating and into the combustion chamber below; it then travels to the remaining components in the boiler. In contrast, Milner teaches a gas outlet 40 located near the top of the boiler, where it would be extremely susceptible to whirled up un-combusted ash particles. The depressions 32 would not collect and allow for the coarse un-combusted ash typical of straw to completely combust and would not prevent it from entering the gas flow.

### **Claim Rejections – 35 USC § 103**

Claims 1-2, 4, 6, 8, 10, and 12 are rejected under 35 U.S.C. § 103(a) as being unpatentable over US 4,498,909 to Milner et al. in view of US 5,901,653 to Jennebach et al., further in view of US 5,720,165 to Rizzie et al. and further in view of US 7,228,806 to Dueck et al.

Claim 1 has been amended to recite that the gasification boiler burns bales of straw and that the fuel and gasification chamber is configured to receive a bale of straw.

Milner does not teach a boiler capable of burning an entire straw bale, but rather teaches a boiler that continuously adds wood and/or wood chips as fuel. (Milner, Col. 1, line 60; Col. 2, lines 35-36; Col. 8, lines 14-15). The fuel is added through a valve 31 into a hopper 33, and then released into the chamber 20 on a continuous basis. (Milner, Col. 2, line 65 to Col. 3, line 14). The chamber 20 is therefore not configured to receive a bale of straw for burning all at one time and Milner teaches away from such a chamber. (See Col. 2, lines 34-44, the constant rate protects the equipment).

Furthermore, Applicant respectfully disagrees with the Examiner's assertion in paragraph 10 of the outstanding office action that because Dueck states that all kinds of biomass can be gasified, it would be obvious to use straw fuel with Milner. As stated in the background section of the present application, straw fuel poses particular problems for gasification, such as difficulty in achieving uniform gasification, low ash melting point, and high content of un-combusted small ash particles.

Attached Exhibits A-C (and translations) further discuss the difficulties of gasification of straw. As stated in Exhibit A, by 1997 wood gasifiers were considered "state of the art," while significant technical problems remained for straw fuel, partially due to higher levels of nitrogen, sulfur, chlorine, and alkalis. (Exhibit A, last paragraph of first page). Exhibit B states that straw has high ash content, a low softening interval, and high amounts of trace elements. (Exhibit B, "problem" paragraph). It further states that straw has up to 10x more ash, 4x more phosphorus, 10x more sulfur, and 100x more chlorine than conventional wood. (Exhibit B, "results" paragraph). Exhibit C, slide 3 states that straw has a 5-15x higher ash content than wood, that straw slags due to high alkali content at temperatures below 800°C, and that straw has higher levels of impurities such as nitrogen, chlorine, and sulfur. Exhibit C, slide 4 shows the relative amounts of impurities in straw (third column) compared to wood, expressed in multiples of wood.

One of ordinary skill in the art is aware of these problems and would not look to Milner, a wood chip boiler, for gasification of straw. Milner issued in 1985, twelve years before Exhibit A states that straw gasification still faces serious obstacles. In addition, Milner teaches using temperatures of about 1100°C to 1300°C, which are much higher than the melting points of salts present in straws (slag occurs at less than 800°C, as noted above in Exhibit C, and some salts in straw have melting points ranging from 300°C to 450°C). Using straw in the boiler of Milner would therefore result in significant slagging. In contrast to Milner, the invention of claim 1 avoids slagging by using large quantities of straw at a time, but at low temperature, resulting in a high quantity of fuel gas while avoiding the issues of slagging. It would also not be obvious to look to Milner because he teaches a boiler based on the reverse flow principle, while the present invention operates as a parallel flow gasifier.

Accordingly, Applicant respectfully submits that claim 1 is patentable over Milner, Jennebach, Rizzie, and Dueck and requests the withdrawal of the rejection under 35 U.S.C. § 103(a) to claim 1.

Claims 3, 5, 7, 9, 11, and 13 rejected under 35 U.S.C. § 103(a) as being unpatentable over '909 in view of '653, '165, and '806 as applied to claims 1 and 5 above, and further in view of US 6,758,149 to Oiwa et al. Claims 3, 5, 7, 9, and 11 depend from claim 1 and are therefore patentable for at least the same reasons as above.

Claim 14 is rejected under 35 U.S.C. § 103(a) as being unpatentable over '909 in view of '653, '165, '806, and '149. Claim 14 has been amended in a manner similar to claim 1 and is therefore patentable for at least the same reasons as above.

Accordingly, Applicant respectfully requests the withdrawal of the rejections under 35 U.S.C. § 103(a) to claims 3, 5, 7, 9, 11, 13, and 14.

### **Conclusion**

Applicant has made a genuine effort to respond to each of the Examiner's objections and rejections in advancing the prosecution of this case. Applicant believes that all formal and substantive requirements for patentability have been met and that this case is in condition for allowance, which action is respectfully requested. If any additional issues need to be resolved, the Examiner is invited to contact the undersigned at his/her earliest convenience.

The Petition fee of \$555.00 is being charged to our Deposit Account No. 02-3978 via electronic authorization submitted concurrently herewith. Please charge any fees or credit any overpayments as a result of the filing of this paper to our Deposit Account No. 02-3978.

Respectfully submitted,

**Christian Herlt**

By: /Adam R. Southworth/  
Adam R. Southworth  
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Date: June 15, 2011

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## Exhibit A



BÜRO FÜR TECHNISCH-FOLGEN-ABSCHÄTZUNG  
BEIM DEUTSCHEN BUNDESTAG

A

Christine Rösch • Detlef Wintzer

## Gasification and pyrolysis of biomass

TAB report no. 049. Berlin 1997, 116 pages

### Summary

The gasification of biomass is a developing energy technology among various systems for the energetic utilisation of biomass which has the following main advantages compared to conventional combustion technologies:

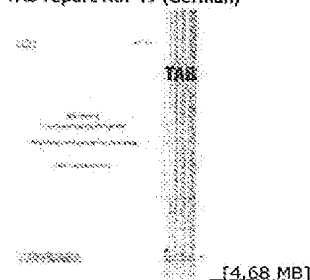
The combined heat and power generation via biomass gasification techniques connected to gas-fired engines or gas turbines can achieve significantly higher electrical efficiencies between 22 % and 37 % compared to biomass combustion technologies with steam generation and steam turbine (15 % to 18 %). If the produced gas is used in fuel cells for power generation, an even higher overall electrical efficiency can be attained in the range between 25 % and 50 %, even in small scale biomass gasification plants and under partial load operation. Due to the improved electrical efficiency of the energy conversion via gasification, the potential reduction in CO<sub>2</sub> is greater than with combustion. The formation of NO<sub>x</sub> compounds can also be largely prevented and the removal of pollutants is easier for various substances. The NO<sub>x</sub> advantage, however, may be partly lost if the gas is subsequently used in gas-fired engines or gas turbines. Significantly lower emissions of NO<sub>x</sub>, CO and hydrocarbons can be expected when the produced gas is used in fuel cells instead of using it in gas-fired engines or gas turbines.

Pyrolysis of biomass generates three different energy products in different quantities: coke, oils and gases. Flash pyrolysis gives high oil yields, but because of the technical efforts needed to process pyrolytic oils this energy generating system does not seem to be very promising at the present stage of development. However, pyrolysis as a first stage in a two-stage gasification plant for straw and other agricultural feedstocks posing technical difficulties in gasification does deserve consideration.

In most biomass gasification processes, air is used as gasifying agent with the result, that a low calorific value gas (3-5 MJ/m<sup>3</sup>) is generated, which can be used after cleaning in gas-fired engines or gas turbines. For gas turbines connected to a steam turbine, medium calorific value gas (12-15 MJ/m<sup>3</sup>) is more favourable than low calorific gas. Steam injection into the gas turbine combustion chamber (Cheng process) requires at least medium calorific value gas. The production of methanol or hydrogen via biomass gasification or the use of producer gas in low-temperature fuel cells also require either gasifiers operating with highly-enriched oxygen and steam or indirectly heated (allothermic) gasifiers must be used with steam as a gasification medium to generate the necessary medium calorific value raw gas with high hydrogen content.

Gasification of wood and wood-type residues and waste in fixed bed or fluidised bed gasifiers with subsequent burning of the gas for heat production is state of the art. The wood gasifiers employed primarily in the Scandinavian countries are used almost entirely for heat generation. Significantly greater technical problems are posed by gasification of straw and other solid agricultural feedstocks, which mostly have higher concentrations of nitrogen, sulphur, chlorine and alkalines. The gasification of herbaceous biomass is still at an early stage of research and development. Intensified

TAB report No. 49 (German)



The printed report can be requested free of charge ([buer@tab-beim-bundestag.de](mailto:buer@tab-beim-bundestag.de)).  
[BibTeX](#) | [RIS](#)

Further information (German)

[Information on the project](#)

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development efforts on gasification technologies for herbaceous biomass feedstocks are desirable as the potential supply of this group of fuels is comparatively large.

Thorough gas cleaning and perfect adaptation of the gas from biomass gasification to the specific requirements of the gas utilisation systems are the prerequisites for gas use in gas-fired engines, gas turbines and fuel cells. Tar compounds can be removed effectively by increasing the gas temperature or by catalytic tar cracking with dolomite or nickel. However, even for wood gasifiers there is still no economically viable solution of the tar problem. None of the gasifier types currently on the market have been successfully tested in connection to gas-fired engines in long term operation under practical conditions in combined heat and power stations.

Under EU demonstration projects, integrated biomass fluidised bed gasifiers with combined cycles (gas and steam turbines) and with an electrical capacity of 5 MW and more are planned, being under construction or in operation. Both gasifiers operating under atmospheric conditions and under pressure (up to 20 bar) and with cold or hot gas cleanup systems are involved in the EU demonstration programme. With pressurised gasification higher overall electrical efficiencies can be achieved, but greater technical and financial resources are required to feed the biomass into the gasifier, and problems with gas cleaning may occur.

For power plants with integrated biomass gasification in the range 3 to 20 MWe, biomass fluidised bed gasification under atmospheric pressure connected to gas turbines, Cheng cycles or gas and steam turbines (IGCC) appear to be the most promising technology at present in technical and economic terms. For combined heat and power stations with capacities up to about 2 MWe, gas use in gas-fired engines is currently more interesting than gas use in gas turbines. Because of problems with fuel supply and logistics, biomass gasification plants with capacities above approximately 30 MWe are not a suitable size for biomass gasification plants in Germany and most other European countries.

The joint combustion of biomass in existing large coal-fired power stations (100 MWe) is currently being investigated in different countries. The integration of biomass-fuelled gasifiers in coal-fired power stations would have different advantages over stand alone biomass gasification plants. Of importance are the greater flexibility in response to annual and seasonal fluctuations in biomass availability and the lower investment costs for the biomass gasification unit.

In case the cleaned and upgraded producer gas is used in fuel cells for power production, the low-temperature proton exchange membrane fuel cell (PEMFC) and the high-temperature molten carbonate fuel cell (MCFC) and solid oxide fuel cell (SOFC) are more attractive in the longer term because of their higher overall electrical efficiency than the medium-temperature phosphoric acid fuel cell (PAFC). Power generation in high-temperature MCFC or SOFC with integrated biomass gasification also has the advantages that no separate unit is needed for CO-shift reaction prior to gas injection into the fuel cell, and that in addition to electricity, process heat is provided by the fuel cell at a high temperature level. For the PEMFC and MCFC, which are on the threshold of the demonstration phase, several companies are aiming to move into small series production in the next few years.

Although each of the fuel cell types listed above has made substantial advances in technological development in recent years, all three types still have several major technical problems to overcome. It remains to be seen which type will overcome its problems most successfully. The start of series production should in any case significantly reduce the present cost disadvantage compared to other gas utilisation techniques. To reach the point of technological maturity for fuel cell systems with integrated biomass gasification (IGFC), extensive R&D work going beyond fuel cell technology is necessary.

Under the frame conditions currently reigning on the energy market there is little motivation for plant manufacturers and potential operators to fund the bulk of R&D work themselves. In this situation, encouraging R&D activities requires not only promoting application related demonstration projects but also R&D in the field of gasification, gas cleaning and gas utilisation. Promotion of further research, development and demonstration projects is recommended, with priority for the following areas:

- Demonstrating low-outage plant operation with an integrated biomass gasification plant (initially wood), a gas cleaning system and gas use in gas motors and gas turbines in regular operation in technical test installations and subsequently in demonstration units.

- Development and technical demonstration of gasifiers for straw and other straw-type biomass and associated gas cleaning processes.

- Integration of units for gasifying or pyrolysing biomass into existing large coal-fired power stations.

- Experimental testing of combining processes for biomass gasification, gas cleaning and gas use in fuel cells.

At present, biomass gasification is starting from an even less favourable economical position than energy use of biomass through combustion, as the technically attractive gasification systems are in an earlier phase of development and demonstration. Assessments on the cost-effectiveness of energy generating systems with integrated biomass gasification have to be proven by practical experience in regular operation. There are, nevertheless, indications that technical advances in developing reliable systems for biomass gasification and efficient gas utilisation can lead to economical advantages over combustion. However, they can only raise heat and power generation from biomass above the break-even point if there is also a significant change in the frame conditions, for example through greater financial reward for the environmental benefits associated with biomass utilisation for energy production. Otherwise the market for biomass gasifiers in Germany and Europe will be limited for the foreseeable future to the treatment of organic wastes (e. g. process residues from the cellulose, paper and sugar industries).

Created: 02/18/2011    Updated: 02/18/2011

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## Strohvergäsung Straw gasification with slagging and plasma technology, dry gascleaning (BLT 043452)

Projektverantwortlicher an FJ-BLT: Dipl.-Ing. Manfred Wörgetter

### Beteiligte Institutionen bzw. Kooperationspartner:

- Austrian Bioenergy Centre GmbH (Projektleitung)
- Institut für Verfahrenstechnik, Umwelttechnik und Techn. Biowissenschaften, TU-Wien
- Institut für Verfahrenstechnik des Industriellen Umweltschutzes, MOU Leoben
- New Plasma GmbH&CoKEG
- FEX-ÖKO-Faserverarbeitungs-GmbH
- Rath Chamottewaren- und Thonöfenfabrik, Aug. Rath jun. GmbH

### Problem-/Aufgabenstellung:

Die Vergasung ist eine Schlüsseltechnologie für die Entwicklung von biomassebasierten Energiesystemen. Durch die thermochemische Umsetzung der festen Biomasse wird ein Gas erzeugt, das zur Strom- und Wärmeerzeugung und für Synthesen eingesetzt werden kann. Auch bei kleinen und mittleren Anlagen zur gekoppelten Strom- und Wärmeerzeugung lassen sich damit günstige elektrische Ausbeuten erzielen. Allerdings konnten sich Stroh und Ganzpflanzen mit ihren ungünstigen verbrennungstechnischen Eigenschaften (hohe Aschegehalte, Aschen mit niedrig liegendem Erweichungsintervall und hohen Gehalten an Spurenstoffen) als Rohstoff für Vergasungsanlagen nicht etablieren.

Im Rahmen des Projektes soll durch gezielt herbeigeführte Ascheschmelze ein Konzept zur Vergasung von Stroh- und Ganzpflanzenprodukten erstellt werden, welches fähig ist, in einem Durchlaufprozess die Biomasse unter vollständiger Ausnützung des enthaltenen Kohlenstoffes in ein energetisch und stofflich verwertbares Produktgas umzusetzen. Um den Prozess mit ausreichender Energiedichte des Brennstoffes betreiben zu können wird pelletiertes Stroh verwendet.

### Ergebnisse:

Entsprechend den brennstofftechnischen Eigenschaften des Strohs wurde das Vergasungssystem ausgelegt. Die Effizienz der Brennstoffumsetzung und die Gasqualität wurden untersucht und beurteilt.

Stroh, ein Nebenprodukt der Landwirtschaft, zeichnet sich durch besondere Eigenschaften aus: Die Struktur ist durch Halmeäste und Knoten geprägt, die Rohdichte ist sehr gering. Stroh besitzt außen eine wachsartige Deckschicht, die nicht mit der Holzrinde vergleichbar ist. Durch den raschen Aufwuchs der Pflanzen sind viele Asche bildende Stoffe mineralischen Ursprungs eingelagert. Der Aschegehalt ist bis zu 10-mal höher wie bei Holz. Durch die landwirtschaftlichen Kulturbedingungen unterliegen N, Na, Cl einer breiten Variation. Stroh enthält bis zu 4-mal mehr Phosphor, bis zu 10-mal mehr Schwefel und bis zu 100-mal mehr Cl als Holz. Es ist daher mit anderen Reaktionsbedingungen und anderen Verunreinigungen des Produktgases zu rechnen. Durch die mineralische Zusammensetzung der Aschen kann Erweichung ab 800 °C und Aufschmelzen bei 1200 °C auftreten.

Die abweichende Faserstruktur besitzt bei gleicher Bezugsmasse eine ungleich höhere äußere Oberfläche und damit Reaktionsfläche. Daraus resultieren unterschiedliche Vergasungsverläufe. Der Pyrolysevorgang setzt verzögert ein, durch die rasche Aufheizung werden die Pyrolyseprodukte rasch freigesetzt. Etwa 70 % der Trockensubstanz werden in Gase und kondensierbare Öle umgesetzt. Der Restkoks ist durch die Anreicherung der Asche charakterisiert. Die Reaktivität des Kokes beeinflusst die Gesamtumsetzung von Stroh maßgeblich. Die Korngröße und die Festigkeit des Kokes sind gering, weshalb nicht mit ruhenden Koks-schüttungen gearbeitet werden kann. Die Pyrolyseprodukte müssen einer abschließenden Vergasung unterzogen werden, wobei der kondensierbare Produktanteil weitgehend eliminiert werden muss (Reformierung mit Wasserdampf und Kohlendioxid und thermischer Zersetzung bei hohen Temperaturen).

Unter oxidierenden Bedingungen treten lokale Temperaturspitzen auf, die eine mikroskopische Aufschmelzung der Asche zu Schlacke bewirken. Unter Vergasungsbedingungen wird geringeres Aufschmelzen erwartet. Um Schlackenbackung zu vermeiden ist man bestrebt, mit schmelzflüssigen Asche/Schlackegemengen zu vergasen.

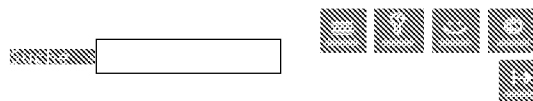
Weitere Informationen können bei Herrn Dipl.-Ing. Manfred Wörgetter per E-Mail oder über die Fax-Nummer +43 (7416) 52175-45 angefordert werden.

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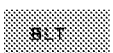
## Exhibit B - Translation

The BLT      Biomass      Logistics      Technology      Service



**BLT**

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The BLT

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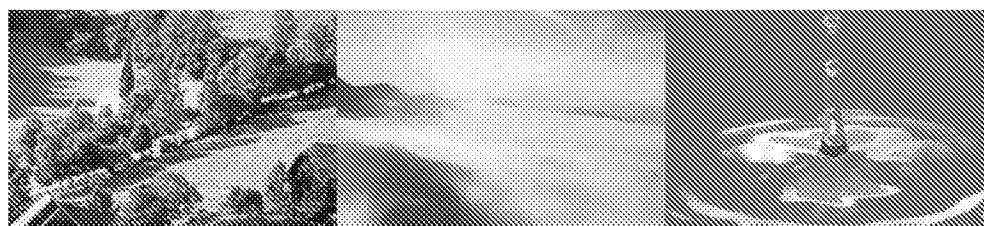
Departments

Biomass

Logistics

Technology

Service



### Straw gasification

Straw gasification and slagging with plasma technology, dry gascleaning (BLT 043 452)

Project Manager at FJ-BLT: Dipl.-Ing. Manfred Wörgetter

#### Participating institutions and cooperation partners:

- ✦ Austrian Bioenergy Centre GmbH (Project Management)
- ✦ Institute of Process Engineering, Environmental and Technical Biology, Technical University of Vienna
- ✦ Institute of Process Engineering of industrial environmental protection, MOU Leoben
- ✦ New Plasma GmbH & CoKEG
- ✦ FEX-ECO-fiber processing GmbH
- ✦ Rath Chamottewaren and Thonöfenfabrik, Aug. Rath jun. GmbH

#### Problem-/Aufgabenstellung:

Gasification is a key technology for the development of biomass-based energy systems. By thermochemical conversion of solid biomass produces a gas that can be used to generate electricity and heat production and synthesis. Even for small and medium-sized plants for cogeneration of electricity and heat generation can be achieved so cheap electrical yields. However, whole crop straw and could, with their poor combustion properties (high ash content, ash having a low softening interval and high contents of trace elements) as feedstock for gasification plants do not establish.

The project is to be created by selectively induced ash melt a concept for the gasification of straw and whole plant products, which is able to implement in a continuous process of biomass in full utilization of the carbon contained in an energy-and material usable product gas. To operate the process with sufficient energy density of the fuel can pelleted straw is used.

#### Results:

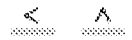
According to the fuel properties of the straw gasification system was designed. The efficiency of fuel conversion and gas quality were examined and assessed.

Straw, a by-product of agriculture, is characterized by specific properties: The structure is characterized by culm and nodes, the density is very low. Straw has a waxy outer layer that is not comparable to the bark. The rapid regrowth of the plants many ash-forming substances are incorporated mineral origin. The ash content is up to 10 times higher than conventional wood. By the agricultural crop conditions are subject to K, Na, Cl a wide variation. Straw containing up to 4 times more phosphorus, up to 10 times more sulfur and up to 100 times more than wood Cl. It is, therefore, reaction conditions and other impurities in the product gas can be expected with others. By the mineral composition of the ash softening can occur from 800 ° C and melting at 1200 ° C.

The different fiber structure has the same reference ground a much greater external surface area and thus reaction. This results in different gasification curves. The pyrolysis process uses delayed by the rapid heating of the pyrolysis products are rapidly released. About 70% of dry matter are converted into gases and condensable oils. The residual coke is characterized by the accumulation of ash. The reactivity of the coke affects the overall implementation of straw significantly. The grain size and the strength of the coke is low, and therefore can not be done with dormant coke charge. The pyrolysis products must undergo a final gasification, wherein the condensable product content must be largely eliminated (reforming with water vapor and carbon dioxide and thermal breakdown at high temperatures).

Under oxidizing conditions, local temperature peaks occur, resulting in a microscopic melting of the ash to slag. Under gasification conditions reduced melting is expected. To avoid Schlackeanbackung, the aim is to gas with molten ash / slag mixtures.

**For more information on Mr. Dipl.-Ing. Manfred Wörgetter via e-mail the fax number +43 (7416) 52175-45 requested or be.**



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**HBLFA LMTZ**

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## **Erste Ergebnisse zur Strohvergasung – Vergleichende Untersuchungen im Labor und im technischen Maßstab**

Dr. Ute Bauermeister

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### **Gliederung:**

- 1. Probleme und Besonderheiten von Stroh als Vergasungsgut**
- 2. Eigenschaften von Biomassepellets im Vergleich**
- 3. Ergebnisse im Laborreaktor**
- 4. Ergebnisse an technischen Pilotanlagen**
- 5. Zusammenfassung**

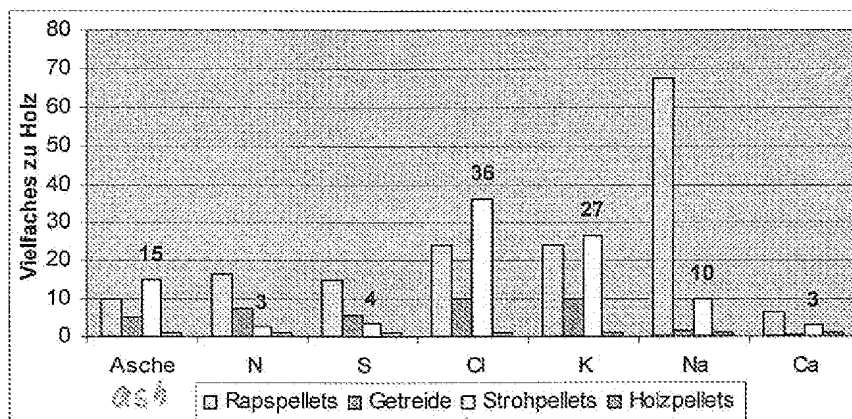
## Eigenschaften von Stroh im Vergleich zu Holz

- **Unterscheidung in Form, Festigkeit, Schüttdichte und Energiedichte**  
Auswirkung auf Lagerung (Staubentwicklung),  
Durchsatz (Energiedichte von Strohhacksel ca. 0,8 GJ/m<sup>3</sup>, von Holz ca. 4 GJ/m<sup>3</sup>),  
Dosierung und Vergasungsverhalten (u.a. Druckverluste im Festbettreaktor),  
Staubgehalt im Rohgas
- **Erhöhter Aschegehalt von Stroh gegenüber Holz**  
5 - 15-fach höherer Aschegehalt von Stroh gegenüber Holz,  
Verschlackungsneigung durch den hohen Alkaliengehalt (Ascheerweichung < 800 °C)
- **Erhöhter Gehalt an N, Cl, S von Stroh und Getreide gegenüber Holz**  
brennstoffbedingt höhere Verunreinigungen von N-, S- und Cl-Verbindungen im Rohgas als bei Holz, mit Auswirkungen auf die Gasreinigung

Auswertung



## Inhaltsstoffe von Biomassen im Vergleich zu Holz



*Stroh pellets*

Mittelwerte, Messungen GNS



## Besonderheiten von Stroh als Vergasungsgut

### Notwendigkeit der Konfektionierung

- Festbettreaktor: niedriger Feinanteil, Kompaktierung oder Pelletierung
- Wirbelbettreaktor: homogene Zerkleinerung
- generell: niedriger Wassergehalt

### Berücksichtigung des Schmelzverhaltens der Asche

- Vermeidung der Verschlackung durch Zusätze oder Temperaturbegrenzung
- Alternativ Vergasungstechnik mit Bildung einer schmelzflüssigen Schlacke bei hohen Temperaturen (Schlackebadvergaser)

### Neue Anforderungen an die Gasreinigung

- Abscheidung von anorganischen Verbindungen aus dem Rohgas
- Abscheidung höherer Staubfrachten

## Verunreinigungen im Rohgas

### Teere

(200 – 4000 mg/Nm<sup>3</sup>)

insbes. abh. vom Verfahrenstyp

### Partikel

(100 – 1000 mg/Nm<sup>3</sup>)

abh. von Brennstoff und Verfahren

### Alkalien, flüchtige Schwermetalle

abh. von der Biomasse

### Halogen-Verbindungen (Chlorid)

abh. von der Biomasse

### N-Verbindungen (NH<sub>3</sub>)

(100 – 7000 mg/Nm<sup>3</sup>)

abh. von der Biomasse

### S-Verbindungen (Sulfid, Sulfat)

abh. von der Biomasse

### Partikelgebundene Verunreinigungen:

kondensierbare Teere, Alkali-, Erdalkali- und Schwermetalle, Koks, Asche, Bettmaterial

### Lösliche Verunreinigungen:

lösliche organische Verbindungen („Teere“) und anorganische Verbindungen

## Strategien zur Vergasung mit geringer Teerbildung

**Vorteil der Gleichstromvergasung** gegenüber der Gegenstromvergasung und Wirbelbettvergasung (Teerspaltung in der Oxidationszone)

**Vorteil der 2-stufigen Vergasung** (Verbrennung des verunreinigten Pyrolysegases, Gaserzeugung nur aus dem Koks)

**Optimierte Prozessführung** mit geringen Schwankungen hinsichtlich (einer niedrigen) Brennstofffeuchte, konstantem Temperaturprofil, angepasstem An- und Abfahrregime (Teerspitzen vermeiden)

**Optimierte Prozessführung** durch das katalytisch-partiellallotherme Verfahren von GNS mit reduzierter Teerbildung in der Pyrolyse

## Biomassevergasung nach dem GNS-Verfahren

**1. Umstellung des Prozesses auf eine katalytische Steuerung**, wobei der Katalysator als billiges Verbrauchsmaterial dem Brenngut vor der Aufgabe in den Reaktor in einem sehr kleinen Anteil zudosiert wurde

**2. Durchführung des Verfahrens partiell allotherm**, indem ein Teil der anfallenden Abwärme dem Prozess wieder zugeführt wird (Brennstofftrocknung, Luftvorwärmung, geringe Dampfzugabe, Rezirkulation).

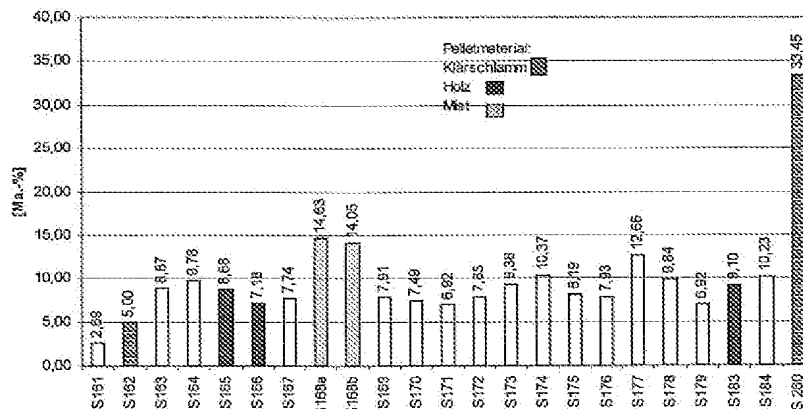
**Vorteile des patentierten GNS-Verfahrens:**

- Steigerung von Durchsatz, Kaltgaswirkungsgrad und Stromausbeute
- hohe Gasreinheit (wenig Teere), hoher Gasheizwert
- Möglichkeit der Temperaturkontrolle durch Dampfzugabe

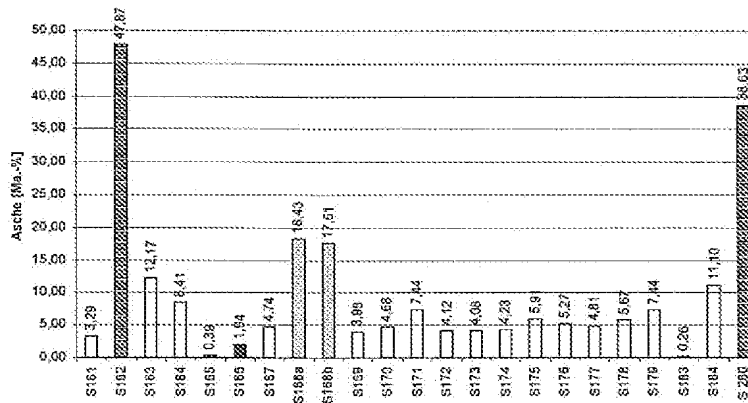
## Erste Untersuchungen zur Gaserzeugung aus Stroh und strohhaltigen Biomassen

- Untersuchung der (thermo-)chemischen Eigenschaften insbesondere von Stroh, Mist, Klärschlamm und Holz (chemische Analyse, Thermoanalyse)
- Untersuchungen zur Vorbehandlung, d.h. Trocknung, Zerkleinerung, Kompaktierung, Pelletierung, Siebanalyse, Druckverlustbestimmung
- Vergleichende Vergasungsversuche im Labormaßstab
- Vergleichende Vergasungsversuche an zwei technischen Pilotanlagen mit ca. 50 kW<sub>el</sub> (Zusammenarbeit mit FÖST e.V. und FBZ e.V.)
  - Forschungs- und Pilotanlage Merseburg (Gleichstrom-Festbettreaktor)
  - Versuchsanlage der Uni Halle (kombinierte Pyrolyse mit stationärer Wirbelschicht)

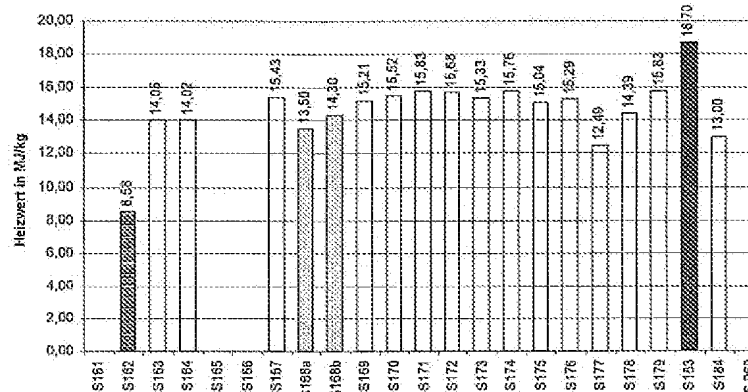
## Eigenschaften von Biomassepellets im Vergleich: Wassergehalt



## Eigenschaften von Biomassepellets im Vergleich: Aschegehalt



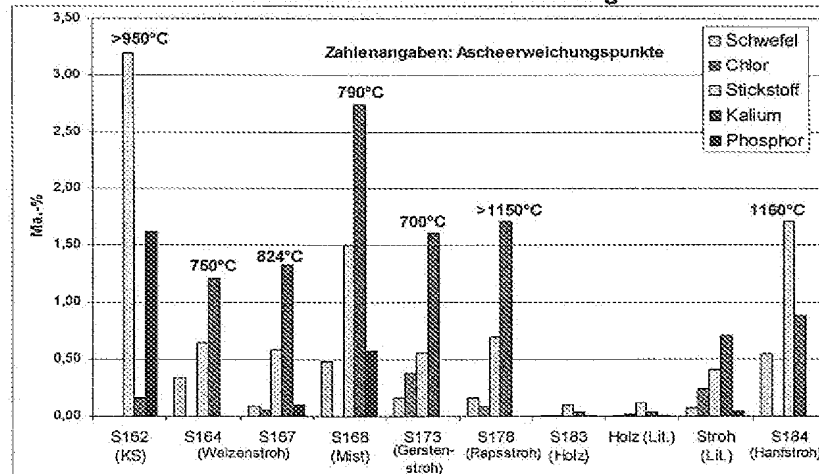
## Eigenschaften von Biomassepellets im Vergleich: Heizwert



✓ höhere Anteile an Asche und Wasser korrespondieren mit entsprechend niedrigeren Heizwerten der Pelletproben



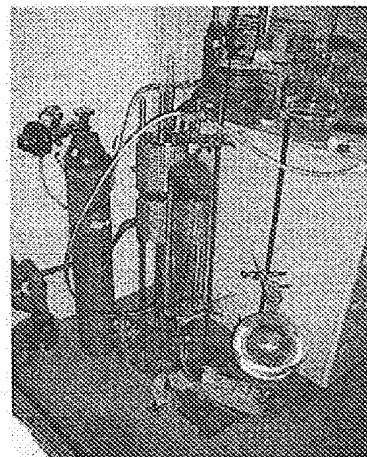
## Eigenschaften von Biomassepellets im Vergleich: Inhaltsstoffe - Ascheerweichung



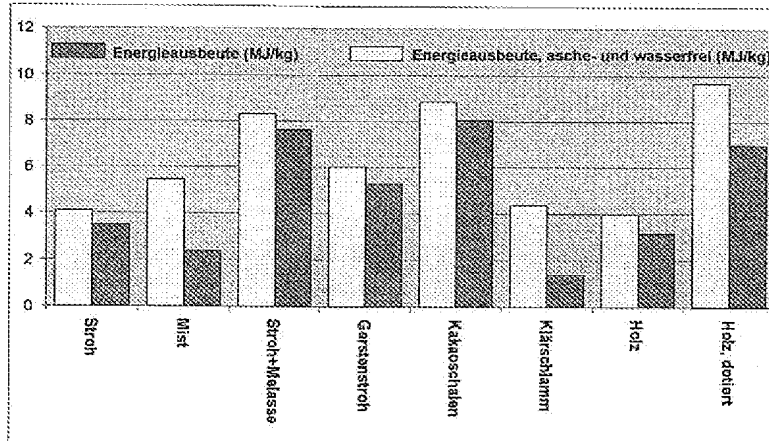
## Vergasungsversuche im Labor

### Versuchsbedingungen:

- diskontinuierliche Versuche
- 2 getrennt regelbare Röhrenreaktoren (bis 1000°C)
- definierte Aufheizgeschwindigkeit
- Vergasungstemperatur 700 °C
- Vergasungsmedien: Luft, Dampf
- Gasmengenerfassung (auch getrennt nach Thermolyse und Reaktolyse)
- Reinigung mit Wasser oder RME



### Energieeffizienz der Vergasung von Biomassepellets im Vergleich zu Holzhackschnitzeln

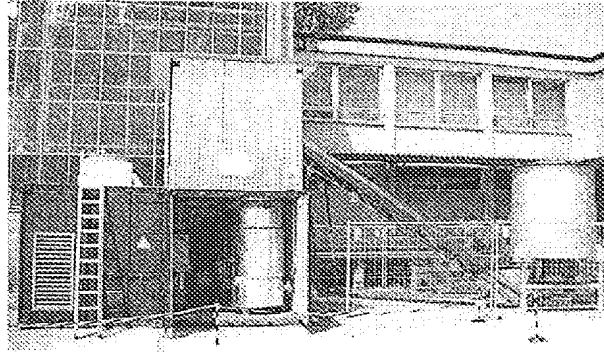


bei Gasheizwerten von 9 bis 12 MJ/m³

### Wirksamkeit der Rohgaswäsche mit Biodiesel für verschiedene Teerkomponenten

Komponente	Holzpyrolyse			Strohpyrolyse		
	ohne Wäsche Experiment 30 [mg/m³]	nach Wäsche mit Biodiesel Experiment 18 [mg/m³]	Reduktion [%]	ohne Wäsche Experiment 33 [mg/m³]	nach Wäsche mit Biodiesel Experiment 27 [mg/m³]	Reduktion [%]
Benzol	4491	363	91,8	370	39	89,4
Toluol	5332	129	97,6	1764	90	94,9
Ethylbenzol	347	5	98,6	268	5,8	97,8
m,p-Xylol	1158	25	97,8	781	20	97
o-Xylol	403	5,8	98,6	280	2,4	99,1
Styrol	480	12	97,5	209	2,9	98,6
C9-Alkybenzole	597	14	98,0	272	4,4	98,4
Naphthalin	184	4,6	97,5	88	4,6	94,8
2-Methylnaphthalin	19	0,6	96,8	10	0,6	94
1-Methylnaphthalin	14	0,5	96,4	6	0,5	91,7

### Forschungs- und Pilotanlage (50 kW<sub>el</sub>), Campus Merseburg



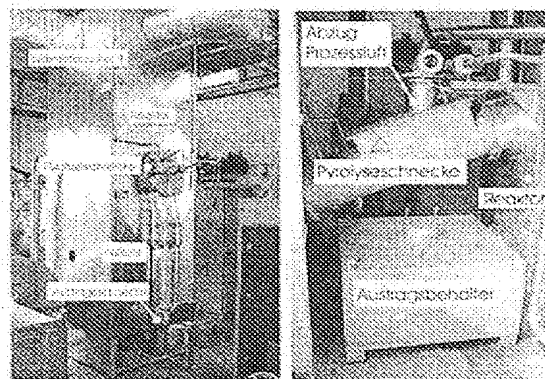
#### Praxisprobleme mit Strohpellets:

Steigende Druckverluste im Reaktorbett  
durch Pelletabrieb  
Aufquellen der Pellets nach Erkalten

#### Vorteile:

Temperaturbegrenzung durch  
Dampfzugabe  
Vermeidung von Verschlackungen

### Versuchsanlage BENA 200 der Universität Halle



#### Praxisprobleme mit Strohpellets:

Verschlackungen im Wirbelbett

#### Vorteile:

Pyrolyseschnecke unempfindlich  
gegen Pelletabrieb

## Gaserzeugung aus Heupellets im Pilotmaßstab (Mittelwerte)

Parameter	Einheit	Halle	Merseburg	Merseburg <sup>1</sup>
Material		Stroh, mit Luft	Stroh, partiell-allotherm	Holz, katalytisch-partiellallotherm (Phase I)
Reaktortemperatur, ca.	°C	900	715-883	900
Durchsatz	kg/h	39	35	40
Gaszusammensetzung	Vol.-%			
CO		12,6	22,2	22
H <sub>2</sub>		8,9	10,4	14
CH <sub>4</sub>		3,6	3	2
CO <sub>2</sub>		14,3	10,4	15
O <sub>2</sub>		0,0	0,0	0
N <sub>2</sub>		60,6	54,1	47
Heizwert (H <sub>u</sub> )	MJ/Nm <sup>3</sup>	3,9	5,0	5,0
Gasvolumenstrom	Nm <sup>3</sup> /h	91,8	56	95
Gasausbeute	Nm <sup>3</sup> /kg	2,4	1,9	2,4
Brennstoffleistung	kW	162	147	167
Gasleistung	kW	98	92	132
Energieausbeute	MJ/kg	9,1	9,4	11,9

<sup>1</sup>: Erste Phase der Umsetzung des GNS-Verfahrens mit Holz

## Untersuchung des Verbleibs und der Entfernung des Brennstoffstickstoffs bei der Vergasung

Brennstoff	Holz	Strohpellets	Strohpellets
Gasreinigung	Wasser	Wasser	RME
NH <sub>3</sub> im Rohgas [g/Nm <sup>3</sup> ]	0,23 – 0,72	4,3 – 7,1	4,3 – 7,1
NH <sub>3</sub> im Reingas [g/Nm <sup>3</sup> ]	0,17 – 0,41	0,92 – 1,36	2,7

Versuche an 3 Pilotanlagen

Gegenüber Holz: bei Stroh ca. 10-facher NH<sub>3</sub>-Gehalt im Rohgas !

70 bis 90% des Brennstoffstickstoffs als Ammoniak im Rohgas !

Reinigungsleistung der Wasserwäsche und RME-Wäsche für Ammoniak aus Strohvergasung unzureichend !

## **Zusammenfassung**

**Hohe Energieeffizienz der Vergasung von Stroh mit niedrigem Teergehalt im Rohgas möglich!**

- Weitere Verbesserung der Energieausbeute durch den Einsatz des katalytisch-partiellallothermen Verfahrens von GNS möglich

### **Anforderungen an die Vergasung von Stroh:**

- Vortrocknung auf <10% als Voraussetzung für eine hohe Gasqualität und hohe Energieeffizienz der Vergasung
- Kompatierung/Pelletierung mit niedrigem Feinanteil als Voraussetzung für den Einsatz im Festbetreaktor
- Vermeidung der Verschlackung: Temperaturbegrenzung in der Reaktolyse und Vermeidung von Temperaturspitzen am Lufteintritt durch Dampfzugabe in Kombination mit vorgewärmter Luft im GNS-Verfahren hat sich bewährt
- Anpassung der Gasreinigung zur Entfernung der gegenüber Holz deutlich höheren Anteile an anorganischen Komponenten wie Ammoniak
- Anpassung der Gasreinigung hinsichtlich der Staubabscheidung
- Anpassung der Reaktordimensionierung an den Aschegehalt

**Vielen Dank für Ihre  
Aufmerksamkeit**

**[www.GNS-Halle.de](http://www.GNS-Halle.de)**

## Exhibit C - Translation

### Characteristics of straw compared with wood

- **Distinction in form, firmness, bulk density and power density**
  - Effect on storage (dust formation),
  - Throughput (power density of straw chaff approx. 0.8 GJ/m<sup>3</sup>, of wood approx. 4 GJ/m<sup>3</sup>),
  - Dosage and gasification behavior (ua pressure losses in the fixed bed reactor),
  - Dust content in the raw gas
- **Increased ash content of straw opposite wood**
  - 5 – 15 fold higher ash content of straw opposite wood,
  - Slagging inclination by the high alkali content (ash softening < 800 °C)
- **Increased content of N, Cl, S of straw and grain opposite wood**
  - fuel-causes higher impurities of n, S and Cl-connections in the raw gas than with wood, with effects on the gas cleanup